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(54) Abstract Title
Training multiple transmitter units during allocated time slots

(57) A communication system is provided having a plurality of remote units respectively having transmitter circuits to facilitate communications. The communication system includes time divided periods 44 such that a first portion of a time divided period 52 is allocated to a respective first remote unit for transmitter tuning operations and wherein this first portion of the time divided period 52 is available for use by a non-allocated, second remote unit for its respective transmitter tuning operations. In this manner, the second remote unit does not have to wait for its own, allocated time divided period in order to perform a transmitter tuning operation. May be applied to Cartesian Feedback, Adaptive Predistortion and LINC (linear amplification using non-linear components) amplification transmitters.

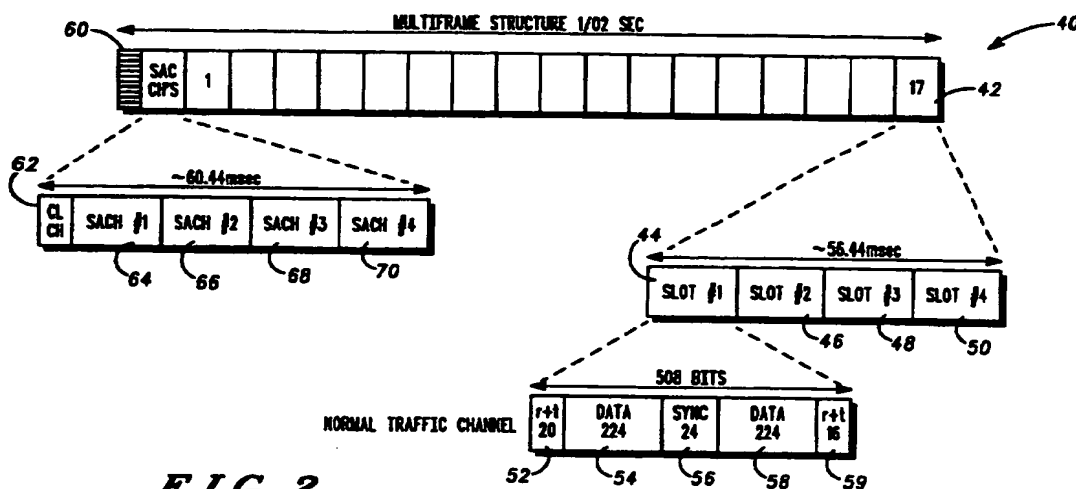


FIG. 2

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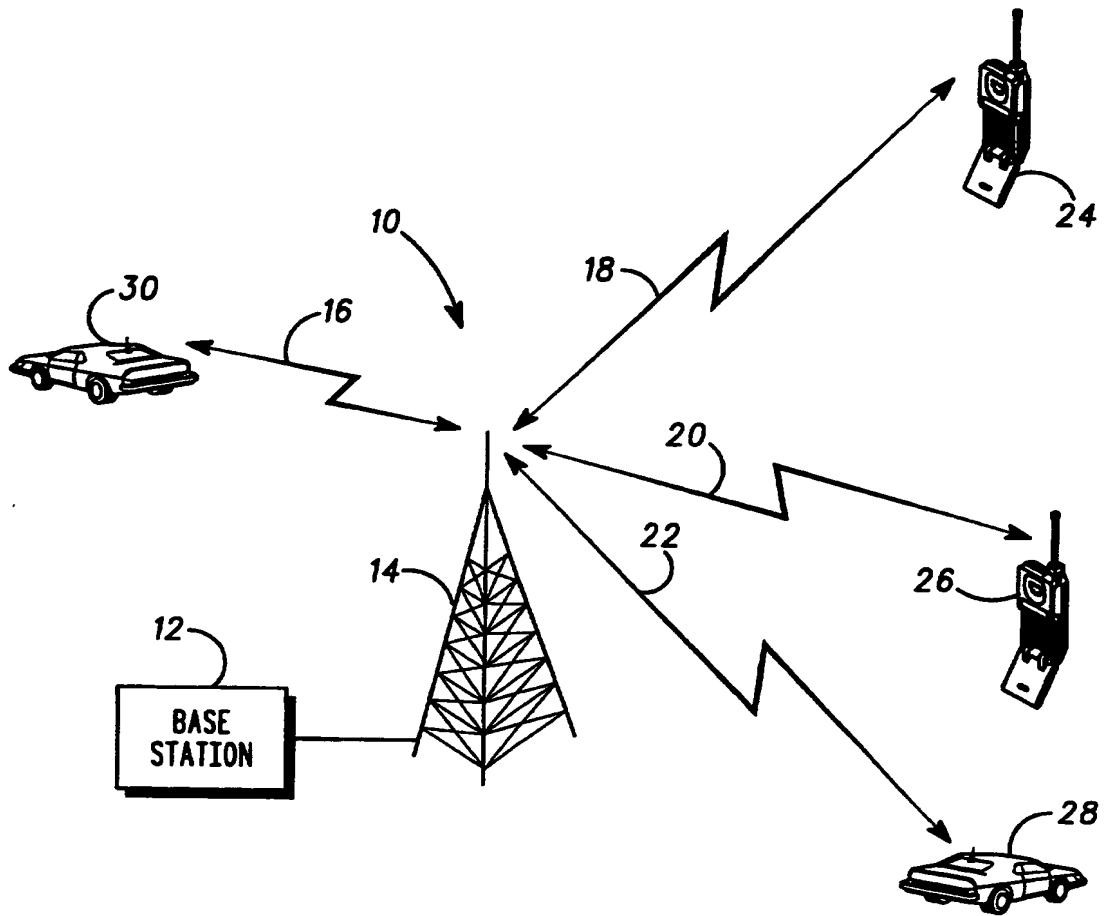


FIG. 1

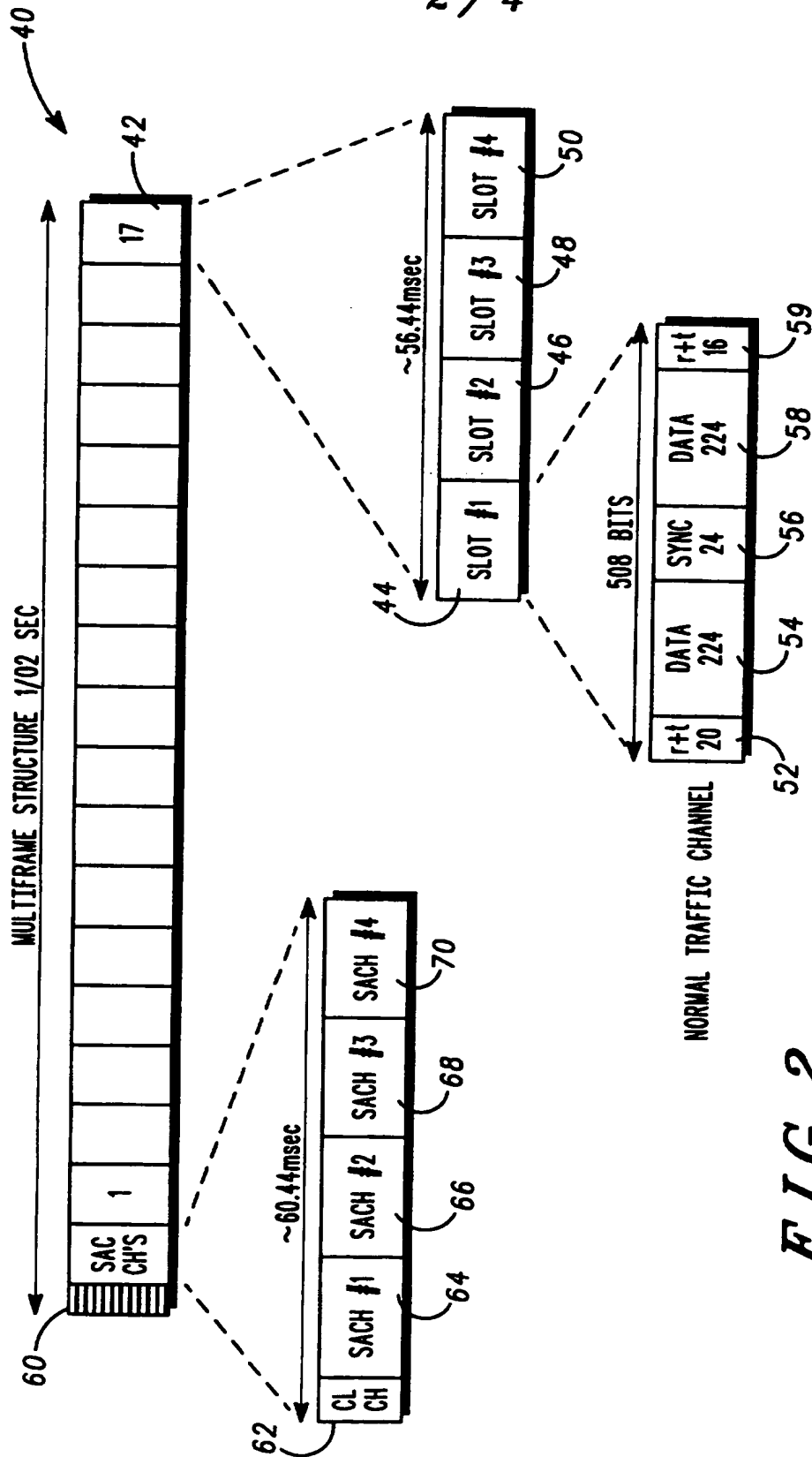
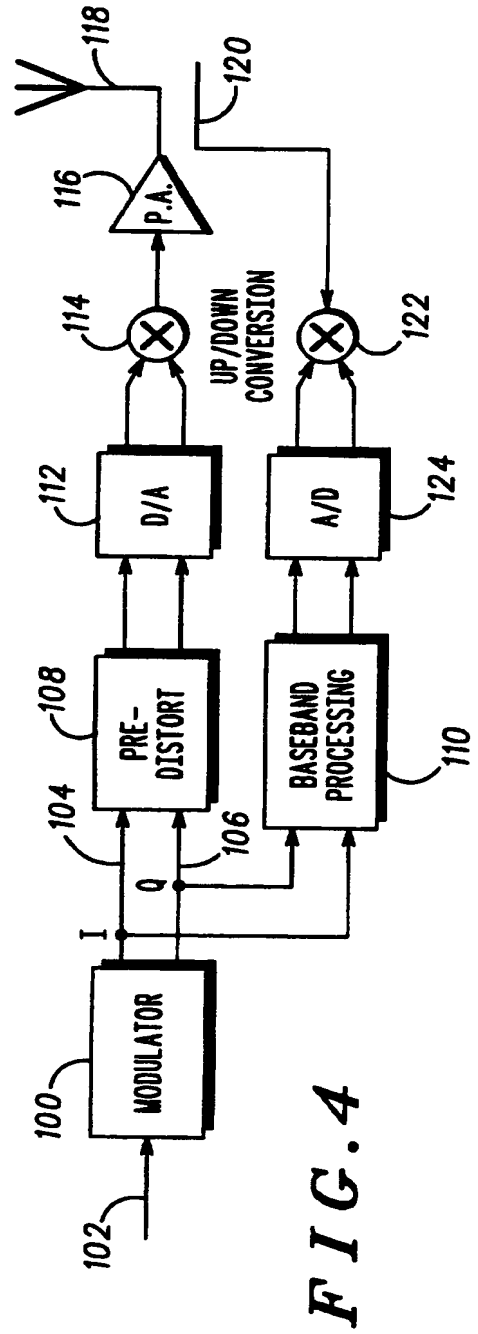
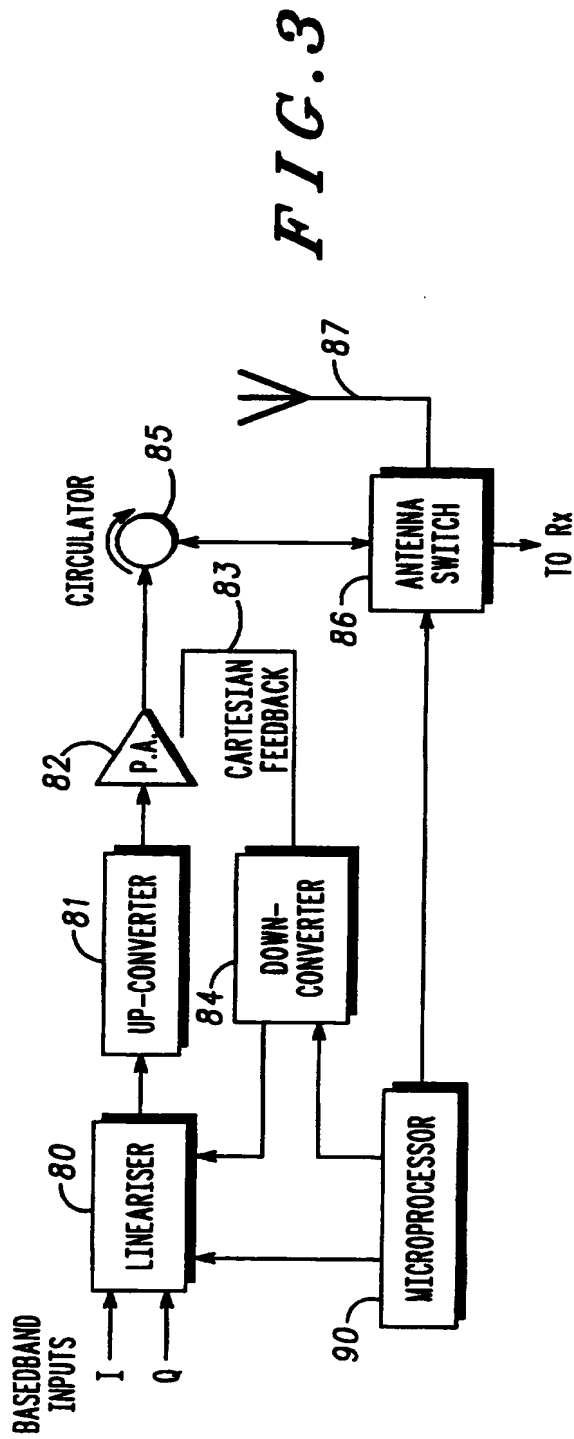
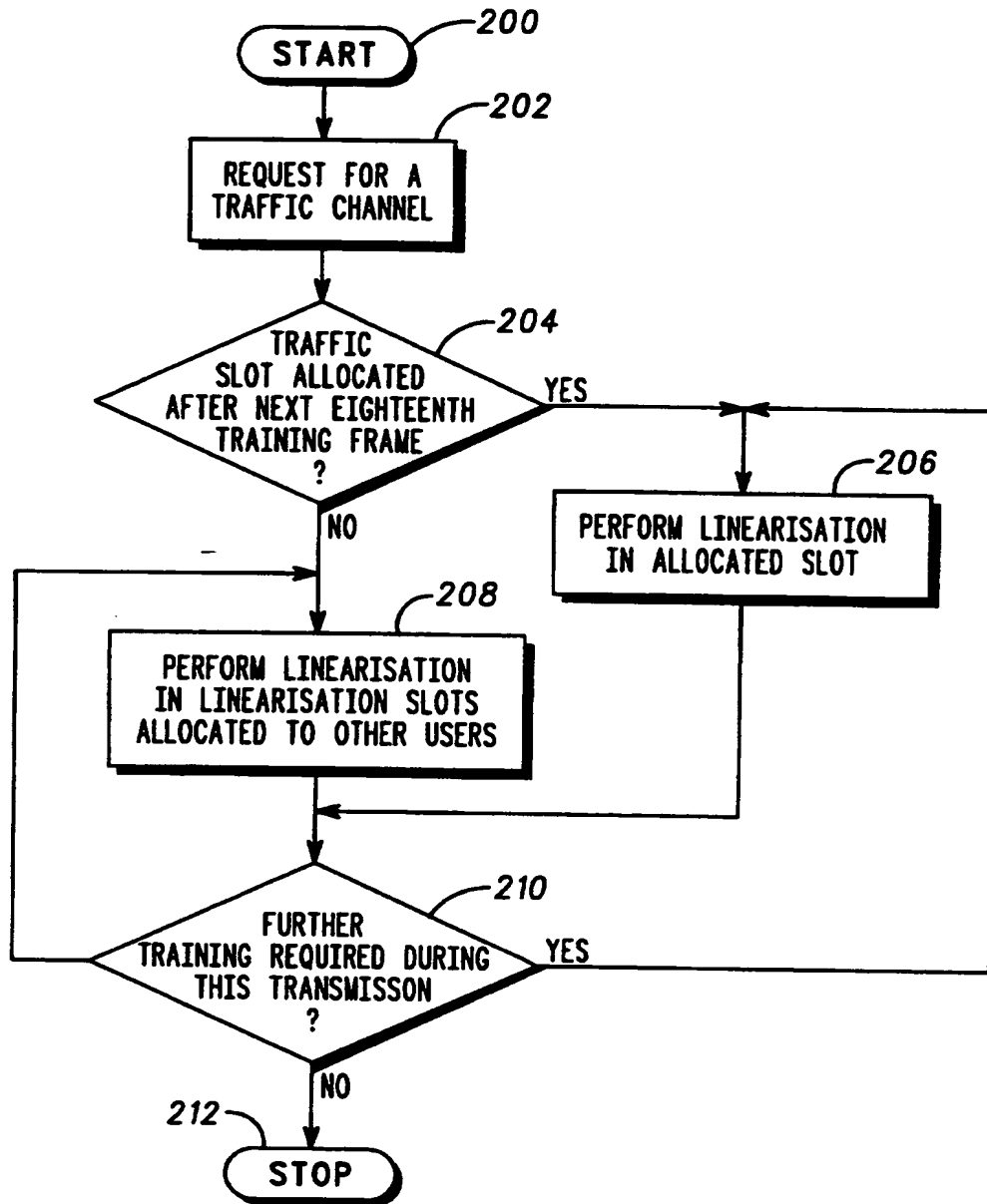


FIG. 2



**FIG. 5**

COMMUNICATION SYSTEM, TRANSMITTER CIRCUIT AND METHOD OF OPERATION THEREFOR

5 Field of the Invention

 This invention relates to communication systems. The invention is applicable to, but not limited to, time division multiple access communications systems, and in particular in the linearisation of
10 radio transmitters in such communications systems.

Background of the Invention

15 Continuing pressure on the limited spectrum available for communication systems is forcing the development of spectrally-efficient linear modulation schemes. Since the envelopes of these linear modulation schemes fluctuate, intermodulation products can be generated in the non-linear power amplifier. Specifically in the private
20 mobile radio (PMR) environment, restrictions on out-of-band emissions are severe (to the order of -60 to -70 dBc) and therefore linear modulation schemes require highly linear transmitters.

 Linear modulation schemes require linear amplification of the modulated signal in order to minimise undesired out-of-band
25 emissions. The actual level of linearity needed to meet particular out-of-band emission limits is a function of many parameters, the most critical of which are modulation type and bit rate. Quantum processes within a typical RF amplifying device are non-linear by nature. Only when a small portion of the consumed DC power is transformed into RF
30 power, can the transfer function of the amplifying device be approximated by a straight line, i.e. as in an ideal linear amplifier case. This mode of operation provides a low efficiency of DC to RF power conversion which is unacceptable for portable units.

 The emphasis in portable PMR equipment is to increase battery
35 life. Hence, such operating efficiencies of the amplifiers used must be maximised. To achieve both linearity and efficiency, so called linearisation techniques are used to improve the linearity of the more efficient amplifier classes, for example class AB, B or C amplifiers.

One such linearising technique often used in designing linear transmitters is Cartesian Feedback. This is a "closed loop" real-time negative feedback technique which 'sums' the baseband feedback signal in their digital "I" and "Q" formats with the "I" and "Q" input signals prior to amplifying and up-converting this signal to the required output frequency and power level.

An alternative linearisation technique is Adaptive Predistortion. In the predistortion system a training signal, generated by baseband digital circuitry is fed through the radio transmitter path where it is amplified, sampled, demodulated and fed back to a baseband processor. From the fed-back signal the gain and phase distortion of the amplifier chain is fully characterised and stored in memory as a table of values. These values are then fed to a predistortion circuit, which distorts the baseband signals in a complementary manner to compensate for the distortion and ultimately produce a substantially linear transmitter output characteristic.

All linearisation techniques require a finite amount of time in which to linearise a given amplifying device. The "linearisation" of the amplifying device is often achieved by applying a training sequence to the amplifying device in order to determine the levels of phase and gain distortion introduced by the device and thus compensate for them. Whilst using such training sequences, a transmitter will inevitably generate non-linear transmissions, which has a significant interference effect on other communication system users. An example of such a training sequence is described in US Patent No. 5066923 of Motorola Inc.

To accommodate for such linearisation requirements, communication systems typically allocate specific training periods for individual users to train their transmitters. The TETRA (Trans. European digital trunked radio) standard includes a time frame, termed a Common Linearisation Channel (CLCH) as is described in UK Patent Application No. 9222922.8, to provide a "full"-training period approximately once every second. The CLCH frame allows a radio to train prior to gaining access to the system. However, a radio having to wait up to one second before training and then accessing the system is undesirable. To assist this significant delay in call set-up times, and also provide an additional period for fine tuning a radio's output characteristics, due to changes in temperature, supply voltage or

frequency of operation, a reduced training sequence has been inserted at the beginning of each TETRA traffic time slot for the radio allocated that slot to perform a minimal amount of training or fine tuning.

5 With the slower linearisation techniques, this slot period for training a transmitter is not sufficient enough to perform a full linearisation procedure. The Adaptive predistortion system is iterative and may take a number of iterations before converging on the final and optimal predistortion characteristic, typically of the order of 4 to 10 msecs. During this time the radio will exhibit a non-linear output
10 performance and will produce unacceptable levels of adjacent channel splatter/ interference.

 This invention seeks to provide an improved communication system arrangement, a transmitter circuit and method of operation, for
15 the linearisation of transmitters.

Summary of the Invention

20 In a first aspect of the present invention a communication system having a plurality of remote units respectively having transmitter circuits to facilitate communications, is provided. The communication system includes time divided periods such that a first portion of a time divided period is allocated to a respective first remote unit for
25 transmitter tuning operations and wherein the first portion of the time divided period is available for use by a non-allocated second remote unit for its respective transmitter tuning operations.

 In this manner, the second remote unit can tune its transmitter operations prior to waiting for an allocated period to perform such
30 functions. In the preferred embodiment of the invention, the transmitter circuits are linearisation transmitter circuits and the transmitter tuning operations include linearity, efficiency and output power adjustments. With first portion of the time divided periods being linearisation training periods, the non-allocated second remote unit
35 utilises the linearisation training period allocated to the respective first remote unit to linearise a signal output from its transmitter, prior to waiting for an allocated linearisation training period and thereby enabling earlier access of the second remote unit to the communication

system. Preferably non-allocated first portions of the time divided periods are additionally and subsequently used for fine-tuning adjustments of the transmitter to continuously optimise its performance.

5 In this manner, tuning operations that affect other users on the communications system, for example linearisation training operations that transmit energy into adjacent frequency channels are prevented from causing interference into such channels when transmitting information as all remote units using the first portion of the time
10 divided periods are training at the same time.

 In a second aspect of the present invention, a transmitter circuit is provided. The transmitter circuit includes an amplifier for amplifying a signal and a tuning circuit, operably coupled to the
15 amplifier for providing the signal to the amplifier such that the signal is optimised when output from the amplifier. A processor is operably coupled to the tuning circuit for providing the signal to the tuning circuit and enabling the transmitter circuit to perform transmitter tuning operations during a tuning period allocated to a second
20 transmitter circuit.

 In the preferred embodiment of the invention, the tuning circuit is a lineariser and the signal output from the amplifier is tuned for at least one of the following: linearity, efficiency, output power.

25 In this manner, the transmitter output signal is optimised as soon as possible before transmission and also between information transmissions, preferably within the same transmission.

 In a third aspect of the present invention a method for optimising at least one parameter of a transmitter circuit is provided. The method
30 includes the step of performing a tuning operation of the at least one parameter during periods allocated to a second transmitter circuit for that respective tuning period.

35 A preferred embodiment of the invention will now be described, by way of example only, with reference to the drawings.

Brief Description of the Drawings

FIG. 1 is a block diagram of communication system, according to a preferred embodiment of the invention.

5 FIG. 2 is a timing diagram of a communication system, according to a preferred embodiment of the invention.

FIG. 3 is a block diagram of a transmitter design according to one embodiment of the invention.

FIG. 4 is block diagram of a transmitter design according to a preferred embodiment of the invention.

10 FIG. 5 is a flowchart of a method of operating a transmitter of FIG. 3 or FIG. 4 in the communication system of FIG. 1 or FIG. 2, according to a preferred embodiment of the invention.

15 Detailed Description of the Drawings

Referring first to FIG. 1, a Time Division Multiple Access (TDMA) communication system 10 is shown. The TDMA communication system 10 includes a base station 12, an antenna 14, radio frequency (RF) communication channels 16, 18, 20 and 22 and a plurality of remote radio stations, for example portable remote radio stations 24, 26 and mobile remote radio stations 28, 30.

At least some of the remote radio stations, for example remote radio station 24, include means for calibration of its respective power amplifier. 25 The base station 12 includes means to synchronise the time slots with the remote radio station. The means for synchronising the time slots can be a micro-controller or any other control means that are known in the art.

The RF communication channels 16, 18, 20, 22 are divided into time slots, for example the timing structure shown in FIG. 2. In the preferred embodiment of the invention, four time slots are equal to a time frame and 30 eighteen frames are equal to a multi-frame.

Referring now to FIG. 2, there is shown a timing diagram according to the preferred embodiment of the invention. The preferred embodiment of the invention is described with reference to the TETRA time division multiple access (TDMA) standard. However, it is within the contemplation of the invention that the invention is equally applicable to alternative digital communications systems having adjacent channel performance 35

specifications that necessitate the use of linearised transmitters. Such communication systems typically provide periods of time that are allocated for lineariser training purposes.

5 The multi-frame structure 40 of the TETRA communications system comprises eighteen frames, seventeen of which are allocated for traffic use, with the eighteenth frame 60 allocated for signalling purposes. The eighteenth frame is a control frame and one of the time slots in that frame is a communication linearisation channel (CLCH) slot for performing say, a phase and amplitude training sequence. Each slot contains information
10 about the slot number and frame number as well as other information. The base station 12 of FIG. 1 controls and updates this information to maintain synchronisation with the remote radio stations.

The traffic frames, for example frame seventeen 42, include four time slots 44, 46, 48, 50, to facilitate four transmission periods for four
15 users. Each traffic slot is divided into a twenty bit period for linearisation and rise time 52, two periods of two hundred and twenty four bits for data transmissions 54, 58, separated by a twenty four bit synchronisation period 56. A sixteen bit ramp down period 59 is allocated to ramp down the transmitter output power gradually.

20 A period of time in the eighteenth frame 60 is allocated for linearisation training - the CLCH sub-slot 62. The CLCH sub-slot 62 provides sufficient time for a "full" linearisation operation of each transmitter. Each transmitter on the system is allowed to use the CLCH sub-slot 62 to train. In this manner, during this period, each transmitter
25 is allowed to splatter into adjacent channels and thereby not affect any traffic communications. The rest of the eighteenth period comprises Slow Associated Control Channel (SACCH) opportunities /slots 64, 66, 68, 70, for transmitting signalling information.

A further training period is provided, on an individual basis, in the
30 TDMA timing structure to enable each transmitter to fine tune its operation immediately before it transmits traffic information on its respectively allocated slot. These periods are provided at the beginning of each slot and comprise twenty bits (approximately = 0.56 msec.), for fine-tuning linearisation and rise time of the transmitter output upto the
35 maximum output power, as shown.

In operation, radio transmitters that require linearisation, and therefore a linearisation period before transmitting data, are no longer required to wait until the CLCH sub-slot 62 on the eighteenth frame in

which to perform a full linearisation operation, but instead use the twenty bit linearisation and rise time 52 periods allocated to other users, to perform some form of linearisation operation, for example fine-tuning operational parameters or performing one iteration of training for an Adaptive Predistortion transmitter.

In this manner any adjacent channel interference generated by this training procedure, within another transmitter's allocated linearisation and rise time 52 period, will not affect the quality of any of the allocated user's information/ traffic transmissions. Hence, each transmitter that trains in this pre-transmission period creates interference at the same time. In such situations, each transmitter must stop performing its linearisation training prior to the particular radio transmitting data in its respective portion of the allocated traffic slot.

Beneficially, an Adaptive Predistortion Linearisation technique is optimised immediately and continually and does not have to wait for the CLCH sub-slot 62 in which to train. Furthermore, if the fine-tuning operation requires a longer period than usual, for example:

(i) in cold conditions where there is a greater change, and rate of change, of temperature of the power amplifier and hence the transmitter characteristics,

(ii) where the radio battery supply voltage needs charging and therefore supplies an irregular voltage to the power amplifier, or

(iii) where the frequency of operation is constantly changing due to say, operating on the fringe of two or three coverage areas and perhaps having to communicate alternately between base stations providing communications for these coverage areas,

then the linearisation and rise time 52 periods allocated to one user, are advantageously used by any transmitter that is able to utilise them.

Referring now to FIG. 3 there is shown a Cartesian Feedback transmitter circuit comprising a lineariser 80, an up-converter 81, a power amplifier 82, a feedback path 83, and a down-converter 84. Connected to the output of the power amplifier 82 is a circulator 85 connected to an antenna switch 86, in turn connected to an antenna 87. A microprocessor 90 controls the lineariser 80 and antenna switch 86 as well as the phase shift introduced into the feedback signal by the down-converter 84. Details of the operation of such a lineariser are described

in the paper "Transmitter Linearisation using Cartesian Feedback for Linear TDMA Modulation" by M Johansson and T Mattsson 1991 IEEE.

A training sequence is input to the lineariser 80 in the form of I and Q samples and is output by the power amplifier 82. During this period, there is Cartesian feedback on the feedback path 83 via the down-converter 84 and a phase comparison is made in the lineariser 80 between the input signal and the feedback signal. A phase shift adjustment is made in the down-converter 84, controlled by the microprocessor 90, in the feedback path so as to optimise the loop phase around the loop and thereby ensure stable operation of the transmitter. When the phase is optimised, the feedback loop provided by the feedback path is closed with the input to the lineariser to provide closed loop operation. Until the phase has been optimised, closed loop operation cannot commence, because of the likelihood of oscillation. Once the phase has been adjusted, the gain in the lineariser 80 is adjusted for maximum efficiency of operation, by increasing the gain until the amplifier enters the "clip" mode. Once this threshold has been detected, the limit of operation of the overall amplifier is set and the amplifier is ready to transmit information, for example voice and/or data. The detecting of this threshold and backing off of the amplifier at the clip point is described in US Patent Application No. 606699. The periods for linearisation and rise time 52, allocated to another user, are utilised by any Cartesian Feedback transmitter, for example by performing a similar phase and/or amplitude training operation.

The lineariser /tuning circuit optimises the performance of the transmitter according to any desired specification, for example to comply with linearity or output power specifications of the communication system or to optimise the operating efficiency of the transmitter power amplifier. Operational parameters of the transmitter are adjusted to optimise the transmitter performance and include as an example, any of the following: amplifier bias voltage level, input power level, phase shift of the signal around the feedback loop. Such adjustments are performed by say, the microprocessor 90.

The preferred embodiment of the invention uses an Adaptive Pre-distortion lineariser as shown in FIG. 4 and as generally described in the paper "Linear Amplification Technique for Digital Mobile Communications" by Y Nagata 1989 IEEE. It is within the

contemplation of the invention, that the particular inventive concept described herein, is applicable to any amplifier tuning method and in particular to all linearised transmitter architectures.

Continuing with respect to FIG. 4 the transmitter comprises a
5 modulator 100 having a data input 102 and outputs 104 and 106
supplying first and second baseband signals, generally known as I and Q. The I and Q signals are fed in parallel to a pre-distortion circuit 108 and a baseband processor 110. As is well known in the art, the pre-distortion circuit 108 predistorts the baseband signals in a manner
10 which is complementary to that introduced in the transmitter amplifier chain so that distortion is substantially cancelled and the radio meets the required level of adjacent channel performance and maximum output power.

The predistorted signal is fed via a digital-to-analog (D/A)
15 converter 112 and up-converter 114 to power amplifier 116, where it is amplified to the final output power level out of the antenna 118.

In order to characterise the amplifier chain to program the predistortion circuit, a portion of the output signal of the power amplifier 116 is sampled by a coupler 120 and fed via down-converter 122
20 and analog-to-digital (A/D) converter 124, to the baseband processor 110.

The baseband processor 110 compares the original (undistorted) I and Q signals with the fed back signals and derives information on the gain and phase changes introduced into the amplified signal in passing through the transmitter chain. From this information, which is stored
25 in memory in the form of a table of values, digital processing in the baseband processor 110 applies a curve-fit routine to the predistortion circuit 108 to predistort the baseband signals as previously described.

As previously mentioned, the Adaptive Predistortion transmitter is iteratively trained by means of a training routine, with a number of
30 iterations required to achieve an acceptable linearisation performance. The training is accomplished by means of a training signal fed to the data input of the modulator and this is performed in periods allocated to that particular user and, if required as applied in this invention, periods allocated to other users. In this manner a number of iterations
35 can be performed to achieve linearisation that much earlier.

During training the amplifier operates non-linearly and generates intermodulation products, which fall into adjacent frequency channels and which may be outside the level set by digital radio

standards specifications for standard traffic communications. Adjacent channel specifications are typically set at far less stringent limits for transmitted output power during training periods.

5 Referring now to FIG. 5, a flowchart showing a method for optimising the performance of a transmitter circuit, for example as shown in FIG. 3, or FIG. 4, according to the preferred embodiment of the invention, is provided. The method includes the steps of requesting a traffic channel for communications, as shown in step 200. If the next
10 traffic channel is allocated for a period following a suitable, allocated linearisation training period being available, as in step 202, the allocated linearisation period is used to train the transmitter, as shown in step 206. However, should a suitable training period not be available before the user has the opportunity of transmitting information on an
15 allocated traffic channel, as in step 202, the transmitter performs linearisation training in linearisation periods allocated to other users, as shown in step 208. If further training is required, either before transmission on the traffic channel or during transmissions, as in step 210, additional training is performed either in the allocated training
20 slots, as shown in step 206, or linearisation slots allocated to other users, as shown in step 208.

Currently in the European Telecommunications Standard Institute (ETSI) Trans. European Trunked Radio (TETRA) standard,
25 transmitter training occurs once per second to allow the transmitter to adapt its performance, and in particular its linearity and efficiency performance, to changing conditions, for example desired output power, frequency, bias voltage, device temperature etc. The present invention preserves these benefits but provides the additional advantage
30 of allowing immediate training opportunities to help resolve any potential access-time problems.

The preferred embodiment uses a novel training technique that provides the capability of training and re-training during linearisation periods allocated to other users without affecting data transmissions of
35 the "allocated" user due to adjacent channel interference.

It is within the contemplation of the invention that the present invention can be equally applied to Code Division Multiple Access

(CDMA) communication systems. Such communication systems provide time-divided periods for transmission on a plurality of frequencies and transmitters would be able to utilise all available training periods on all frequencies, both assigned to that particular transmitter, and to those not assigned to that transmitter.

A disadvantage associated with most amplifier and transmitter designs is the limitation of not being able to always transmit at optimum efficiency. This is primarily due to the characteristics of a power amplifier being dependent upon a number of factors including frequency of operation, operating temperature, bias voltage, input power level etc. that constantly vary over time. Using the proposed linearisation technique, a transmitter has an increased opportunity to maximise, and subsequently maintain, its operating efficiency.

It is also within the contemplation of the invention, that the proposed linearisation training technique can be applied to any linear transmitter method. Linearised transmitter techniques such as Linear amplification using Non-linear Components (LINC) or one of the feedforward techniques are utilised when a wideband transmitter performance is required. Such linearised transmitter technologies still require a significant amount of fine tuning to ensure a linear output. Typically, a feedback path for the transmitted signal is not used in such techniques for fine-tuning purposes as this would severely restrict the bandwidth of operation. However, with the opportunity of training in other radio units allocated training periods, as proposed in the present invention, such fine tuning operations can be performed.

Thus, a communication system, transmitter circuit, and method of operation therefor, are provided giving an improvement over linearisation techniques provided by current technologies.

Claims

1. A communication system having a plurality of remote units respectively having transmitter circuits to facilitate communications,
5 the communication system comprising:
time divided periods such that a first portion of a time divided period is allocated to a respective first remote unit for transmitter tuning operations and wherein the first portion of the time divided period is available for use by a non-allocated second remote unit for its
10 respective transmitter tuning operations.
2. The communication system according to claim 1, wherein the transmitter circuits are linearisation transmitter circuits and the transmitter tuning operations include any of the following transmitter
15 performance adjustments: linearity, efficiency, output power.
3. The communication system according to claim 2, wherein the first portion of the time divided periods are linearisation training periods and the non-allocated second remote unit utilises the
20 linearisation training period allocated to the respective first remote unit to linearise a signal output from its transmitter, prior to waiting for an allocated linearisation training period and thereby enabling earlier access of the second remote unit to the communication system.
- 25 4. The communication system according to any one of the preceding claims, wherein allocated and non-allocated first portions of the time divided periods are subsequently available for use by remote units in fine-tuning adjustments of their transmitter performance.
- 30 5. The communication system according to any one of the preceding claims wherein the allocated first portion of the time divided period occurs prior to a second portion of the time divided period used for transmitting information and transmissions from allocated or non-allocated remote units on the first portion of the time divided period do
35 not affect quality of the subsequently transmitted information.
6. The communication system according to any one of the preceding claims wherein the communication system is one of the following: a

time division multiple access communication system, a code division multiple access communication system.

- 5 7. A transmitter circuit comprising:
 an amplifier for amplifying a signal;
 a tuning circuit, operably coupled to the amplifier for providing
the signal to the amplifier such that the signal is optimised when
output from the amplifier; and
 a processor operably coupled to the tuning circuit for providing
10 the signal to the tuning circuit and enabling the transmitter circuit to
perform transmitter tuning operations during a tuning period allocated
to a second transmitter circuit.
- 15 8. The transmitter circuit of claim 7, wherein the tuning circuit is a
lineariser and the signal output from the amplifier is tuned for at least
one of the following: linearity, efficiency, output power.
- 20 9. The transmitter circuit according to claim 7 or 8, wherein an
operational parameter of the transmitter is adjusted to perform the
tuning operation and the operational parameter includes any of the
following: amplifier bias voltage level, input power level, phase shift.
- 25 10. The transmitter circuit according to any one of claims 7 to 9,
wherein the transmitter circuit is one of the following: Cartesian
feedback transmitter circuit, Pre-distortion transmitter circuit, LINC
transmitter circuit.
- 30 11. The transmitter circuit according to any one of claims 7 to 10, for
operation in any one of the following communication systems: time
division multiple access, code division multiple access.

12. A method for optimising at least one parameter of a transmitter circuit, the method comprising the step of:

5 performing a tuning operation of the at least one parameter of the transmitter circuit during tuning periods allocated to a second transmitter circuit.

13. The method for optimising at least one parameter of a transmitter circuit in accordance with claim 12, wherein the transmitter circuit is a linearisation transmitter circuit and
10 adjustment of the at least one parameter improves at least one of the following: linearity, efficiency, output power.

14. The method for optimising at least one parameter of a transmitter circuit in accordance with claims 12 or 13 further
15 comprising the steps of:

transmitting a request for a communications channel;
transmitting information from the transmitter circuit after
performing a tuning operation; and
re-tuning the at least one parameter of the transmitter circuit
20 during a communication session on allocated or non-allocated tuning periods.

15. A transmitter circuit substantially as described herein with respect to FIG. 3 or FIG 4 of the drawings.

25 16. A communication system substantially as described herein with respect to FIG. 1 or FIG. 2 of the drawings.

30 17. A method of optimising a transmitter circuit substantially as described herein with respect to FIG. 5 of the drawings.



Application No: GB 9701522.6
Claims searched: 1 to 17

Examiner: Mr Jared Stokes
Date of search: 20 March 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H3W (WUL, WVT, WVX)
H4L (LETXX)

Int Cl (Ed.6): H03F (1/32)
H04B (7/005, 7/26)
H04L (27/36)

Other: On-Line - WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB 2 272 133 A (Motorola) See abstract	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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